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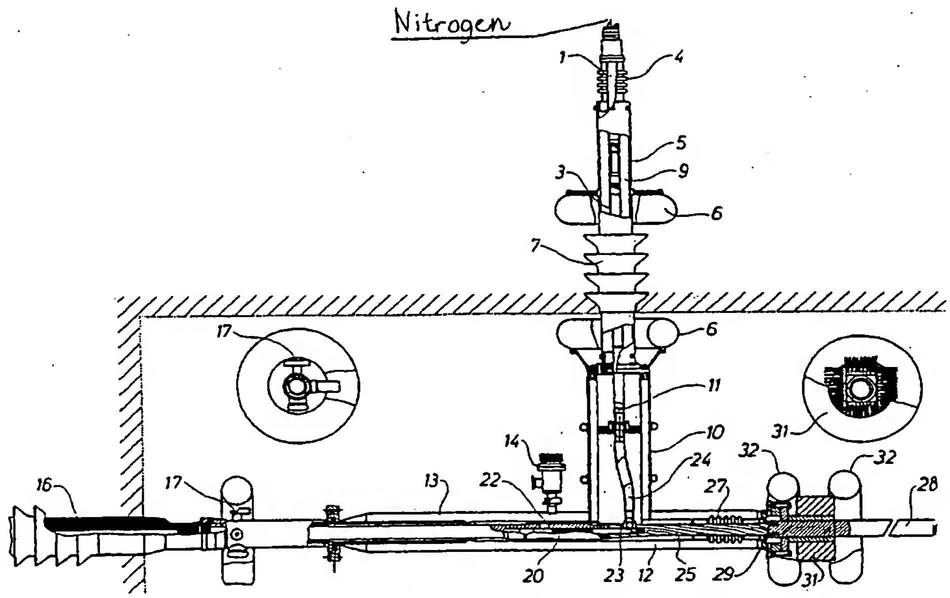
(54) Title: A TERMINAL CONNECTION FOR A SUPERCONDUCTIVE CABLE



(57) Abstract: A terminal connection of a superconductive cable comprising a thermally insulating high-voltage cable through whose interior liquid nitrogen flows. The superconductive cable comprises a plurality of superconductive tapes which are in connection with a copper block (20), which is likewise cooled by means of the liquid nitrogen, and is in connection via flexible electrical conductors (25) with a top bolt (28) which may be connected to electrical equipment at room temperature. Via a T member, the liquid nitrogen is in connection with a cooling machine which is electrically insulated from the remaining part of the terminal connection.

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A terminal connection for a superconductive cable

The invention relates to a terminal connection for a superconductive cable for electrical equipment at room temperature and comprising thermally insulated superconductive tapes wound around a former through whose interior a coolant, such as liquid nitrogen, flows.

US Patent No. 6,049,036 discloses a terminal for connecting a superconductive multi-phase cable to electrical equipment at room temperature. A drawback of this structure is that it takes up relatively much space.

The object of the invention is to provide a terminal connection of the type mentioned in the opening paragraph which takes up less space than known before.

A terminal connection of the type mentioned in the opening paragraph is characterized according to the invention in that the superconductive tapes are in connection with one or more electrically conducting bodies, which are likewise cooled by means of the coolant, and are in connection by means of flexible electrical conductors with a connection terminal which may be connected to the electrical equipment at room temperature, and that the coolant is in connection with a cooling machine via a branch mounted axially relative to the superconductive cable, said cooling machine being electrically insulated from the remaining part of the terminal connection. This provides a terminal connection which takes up less space than known before, and which simultaneously withstands very high electrical voltages.

Further, according to the invention, the electrically conducting bodies may be provided with channels in which the coolant flows. This results in a more effective cooling per unit of length so that shorter lines may be used, thereby allowing a more compact structure.

Moreover, according to the invention, the electrically conducting body or bodies may be of metal, e.g. Al, Ag, Au or Cu, preferably Cu, which are good electrical conductors and easy to work mechanically.

Also, according to the invention, the terminal connection may be adapted to be rotated in an axial direction relative to the superconductive tape, thereby allowing the unit to be mounted easily on a fixedly mounted cable end.

In addition, according to the invention, the axially mounted branch may comprise a flexible pipe. This facilitates the mounting.

In a particularly expedient embodiment, the connection of the coolant to the cooling machine may comprise a thermally and electrically insulated pipe and a compensator for compensating changes, if any, in the longitudinal direction. The pipe may e.g. be made of a composite material, preferably glass fibre.

Further, according to the invention, each of the flexible electrical conductors may consist of a multiple of electrical conductors. This gives an increased flexibility at cooling.

Furthermore, according to the invention, a heat exchanger may be inserted in connection with the connection termi-

nal. The heat exchanger may hereby cool at high power and heat at low power. This prevents icing up of the terminal/bolt. The heat exchanger may e.g. consist of cooling plates/fins.

In a particularly expedient embodiment, the thermal insulation of the superconductive tapes comprises a vacuum chamber with a vacuum valve, said vacuum valve being arranged such that the connection between the vacuum chamber and the cooling machine, in which the coolant flows, serves as an electrical shield of the vacuum valve.

In a particularly expedient embodiment, the connection between the vacuum chamber and the superconductive cable comprises a Johnston coupling.

In a particularly expedient embodiment, the connection terminal is a top bolt adjustable in an axial direction.

In a particularly expedient embodiment, the top bolt provides an airtight sealing of the inner part of the terminal connection.

The invention will be explained more fully below with reference to the drawing, in which

fig. 1 shows a longitudinal section through a terminal connection according to the invention, and

fig. 2 is a section through a copper block in the terminal connection having some through-going cooling channels through which a coolant flows.

Farthest to the left in fig. 1, a thermally insulated superconductive high-voltage cable is shown, which is connected to electrical equipment at room temperature via a terminal connection according to the invention.

The superconductive high-voltage cable, which comprises a plurality of superconductive tapes wound around a former, is kept cooled by means of a coolant, such as liquid nitrogen, which flows through the former. The outer insulation is stripped at the end of the superconductive cable before it is inserted into the terminal connection, which is in the form of a branch, e.g. in the form of a T member, axially mounted relative to the superconductive cable. In the T member, the superconductive cable is surrounded by a vacuum chamber 12 which serves to provide a thermal insulation. A Johnston coupling 15 is inserted between the vacuum chamber 12 and the cable cryostat. The vacuum chamber 12 is evacuated via a vacuum valve 14 connected thereto, said vacuum valve being arranged at a point where there is a low electrical field gradient. During the actual cooling, the inner part of the vacuum chamber 12 must be capable of contracting relative to the outer part. This is made possible by means of a compensator in the form of a flexible bellows member 27, which is arranged at the other end of the T member. At the other end of the T member, there is moreover mounted a connection terminal in the form of an axially adjustable top bolt 28, which provides an airtight sealing of the inner part of the terminal connection and serves as a connection terminal. The superconductive cable is terminated in that the former is introduced into a central bore of an electrically conducting body of metal, such Al, Ag, Au or Cu, preferably Cu, since Cu is relatively easy to work. Alternatively, several electrically conducting bodies may

be provided. The individual, electrically conducting body may e.g. be formed by a copper block 20, said superconductive tapes being soldered by means of ordinary soldering pewter to the copper block 20 in an annular groove at the end of it. Fig. 2 shows the copper block 20 on a large scale. The central bore to the left serves to insert the former which, after the insertion, is tightened by means of some screws which are inserted via some rearwardly positioned cuts. The liquid nitrogen is conveyed from the former into some small channels (a total of 7) in the copper block 20 to obtain a better cooling of it because of the generation of a turbulent flow in the channels, said channels being dimensioned such that they just give rise to a limited pressure drop during the flow therethrough. The liquid nitrogen is then conveyed to a bend 23 which is screwed into the other end of the copper block 20. Counter tightening is effected by means of a counter bolt. The copper block 20 constitutes the transition from superconductors to normal conductors which almost have room temperature. The liquid nitrogen is conveyed from the bend 23 via a flexible hose 24 up through a pipe of composite material, such as glass fibre, to a cooling machine. The glass fibre pipe 1 serves as an electrically insulating transition pipe which conveys the liquid nitrogen from high-voltage potential to earth potential. At each end, the glass fibre pipe 1 is connected with a small steel pipe by gluing and has such a length that a voltage drop of about 36 kV does not give rise to electrical breakdown between the steel pipes. The liquid nitrogen is conveyed from the cooling machine, which is at a low voltage potential, via the pipe 1 to the flexible hose 24 in the vacuum chamber, which is at a high voltage potential.

The glass fibre pipe 1 is mounted in an outer glass fibre pipe 5 which has a suitable diameter, e.g. 90 mm. The space between the pipes 1 and 5 is filled with an electrically insulating foam of the Expancel type. This foam is to ensure a low thermal influx to the inner pipe 1, while preventing electrical breakdown between the high voltage and low voltage parts. Further, between the high voltage and low voltage parts there are mounted some external corona rings 6 for the control of the electrical field as well as some silicone rubber discs 7 for the prevention of breakdown in the event that condensed water vapour is present on the surface of the outer pipe 5.

Thermal contraction at cooling of the pipe structure is compensated for by means of the bellows-shaped compensator which is positioned in the vicinity of the cooling machine.

The current conductor to hot area is soldered by means of ordinary soldering pewter to the other end of the copper block 20 in an annular groove. This current conductor is configured in such a manner that the sum of the heat dissipated in the conductor because of ohmic losses, and the heat admitted from hot area is as low as possible. The current conductor is flexible to enable it to contract at cooling. This flexibility is achieved by dividing the current conductor into a large number of loosely arranged and optionally twisted thin conductors.

These thin conductors are in connection with the top bolt 28, which constitutes the connection to the mains in general or electrical equipment at room temperature, e.g. a transformer. The thin conductors are soldered to the top bolt 28 in an annular groove at the end of it. The top

bolt 28 is a solid copper rod with threads at one end for screwing into the top of the chamber. The top bolt 28 is clamped to the vacuum chamber by means of a relatively large brass bolt 30 on which cooling fins 31 are mounted. These cooling fins 31 are to prevent icing when the current in the cable is low, and to counteract possible heating in case of a brief overcurrent. Some corona rings 32 are provided on their respective sides of the cooling fins 31, said corona rings serving to prevent discharges from the sharp edges of the cooling fins 31.

A heat exchanger may optionally be arranged in connection with the top bolt (the connection terminal).

Helium at a slight positive pressure relative to the atmosphere may be fed to the space around the current conductor optionally via a special opening. Condensation because of possible leaks is avoided hereby.

Some preferred embodiments have been disclosed above, but it should be stressed that the invention is not restricted to these, but may be embodied in other ways within the scope of the following claims.

Patent Claims:

1. A terminal connection for a superconductive cable for electrical equipment at room temperature, comprising thermally insulated superconductive tapes wound around a former through whose interior a coolant, such as liquid nitrogen, flows, characterized in that the superconductive tapes are in connection with one or more electrically conducting bodies (20), which are likewise cooled by means of the coolant, and are in connection by means of flexible electrical conductors with a connection terminal (28) which may be connected to the electrical equipment at room temperature, and that the coolant is in connection with a cooling machine by a branch mounted axially relative to the superconductive cable, said cooling machine being electrically insulated from the remaining part of the terminal connection.

2. A terminal connection according to claim 1, characterized in that the electrically conducting bodies (20) are provided with channels in which the coolant flows.

3. A terminal connection according to claim 1 or 2, characterized in that said one or more electrically conducting bodies are of metal, e.g. Al, Ag, Au or Cu, preferably Cu.

4. A terminal connection according to one or more of claims 1-3, characterized in that it is adapted to be rotated in an axial direction relative to the superconductive cable.

5. A terminal connection according to one or more of claims 1-4, c h a r a c t e r i z e d in that the axially mounted branch comprises a flexible pipe (1).

6. A terminal connection according to one or more of claims 1-5, c h a r a c t e r i z e d in that the connection of the coolant to the cooling machine comprises a thermally and electrically insulating pipe (1) and a compensator for compensating for changes, if any, in the longitudinal direction.

7. A terminal connection according to one or more of claims 1-6, c h a r a c t e r i z e d in that each of the flexible electrical conductors consists of a multiple of electrical conductors.

8. A terminal connection according to one or more of claims 1-7, c h a r a c t e r i z e d in that a heat exchanger is inserted in connection with the connection terminal.

9. A terminal connection according to one or more of claims 1-8, c h a r a c t e r i z e d in that the thermal insulation of the superconductive tapes comprises a vacuum chamber (12) with a vacuum valve (14), and that the vacuum valve (14) is positioned such that the connection between the vacuum chamber (12) and the cooling machine, in which the coolant flows, serves as an electrical shield of the vacuum valve (14).

10. A terminal connection according to one or more of claims 1-9, c h a r a c t e r i z e d in that the vacuum chamber is in the form of a T member so that the branch in which the coolant is in connection with the cooling

machine extends substantially perpendicularly to the winding axis of the superconductive tapes.

11. A terminal connection according to one or more of claims 1-10, c h a r a c t e r i z e d in that the connection between the vacuum chamber (12) and the superconductive cable comprises a Johnston coupling (15).

12. A terminal connection according to one or more of claims 1-11, c h a r a c t e r i z e d in that the connection terminal is a top bolt (28) adjustable in an axial direction.

13. A terminal connection according to claim 12, c h a r a c t e r i z e d in that the top bolt (28) provides an airtight sealing of the inner part of the terminal connection.

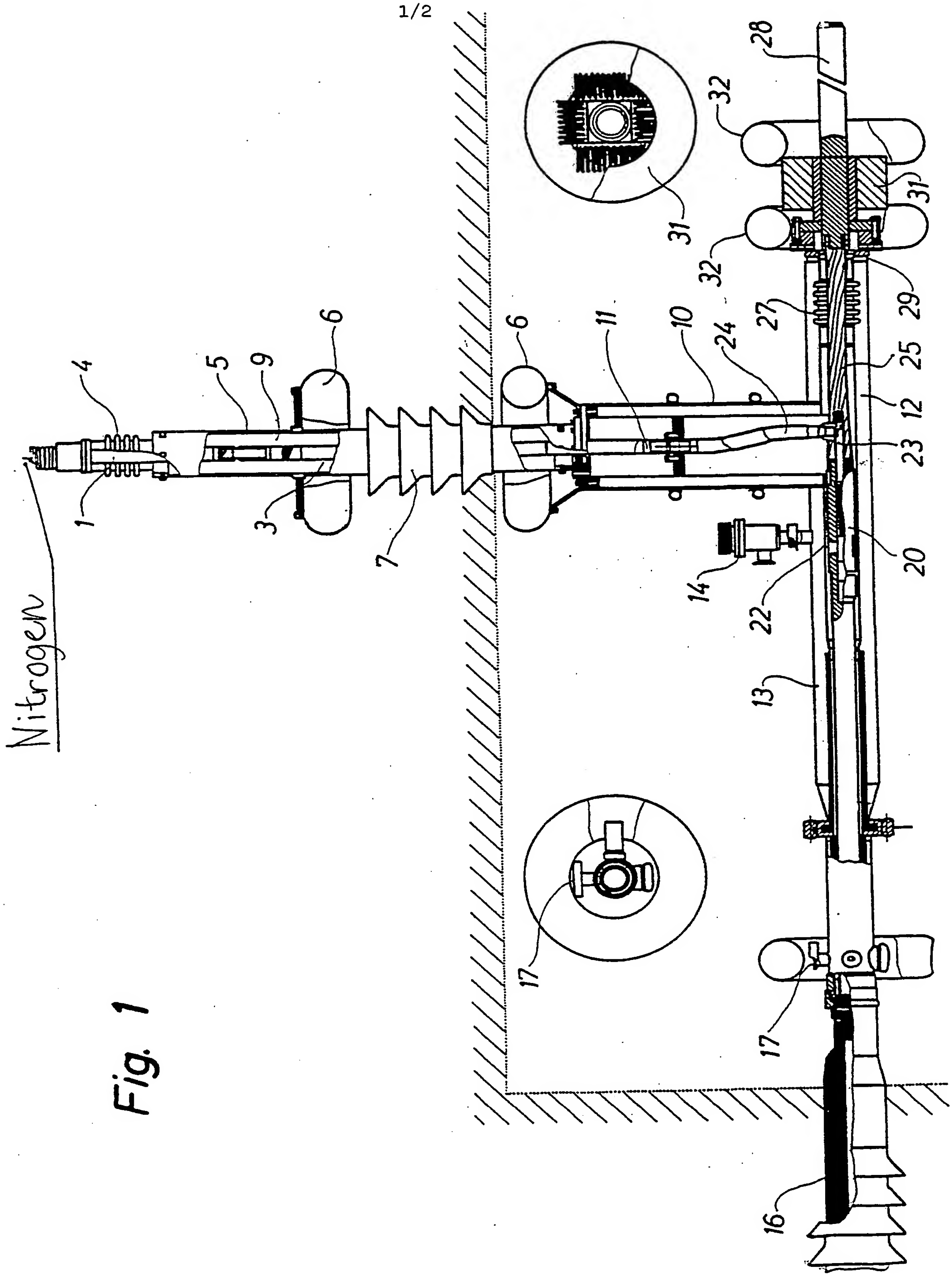
Nitrogen
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Fig. 1

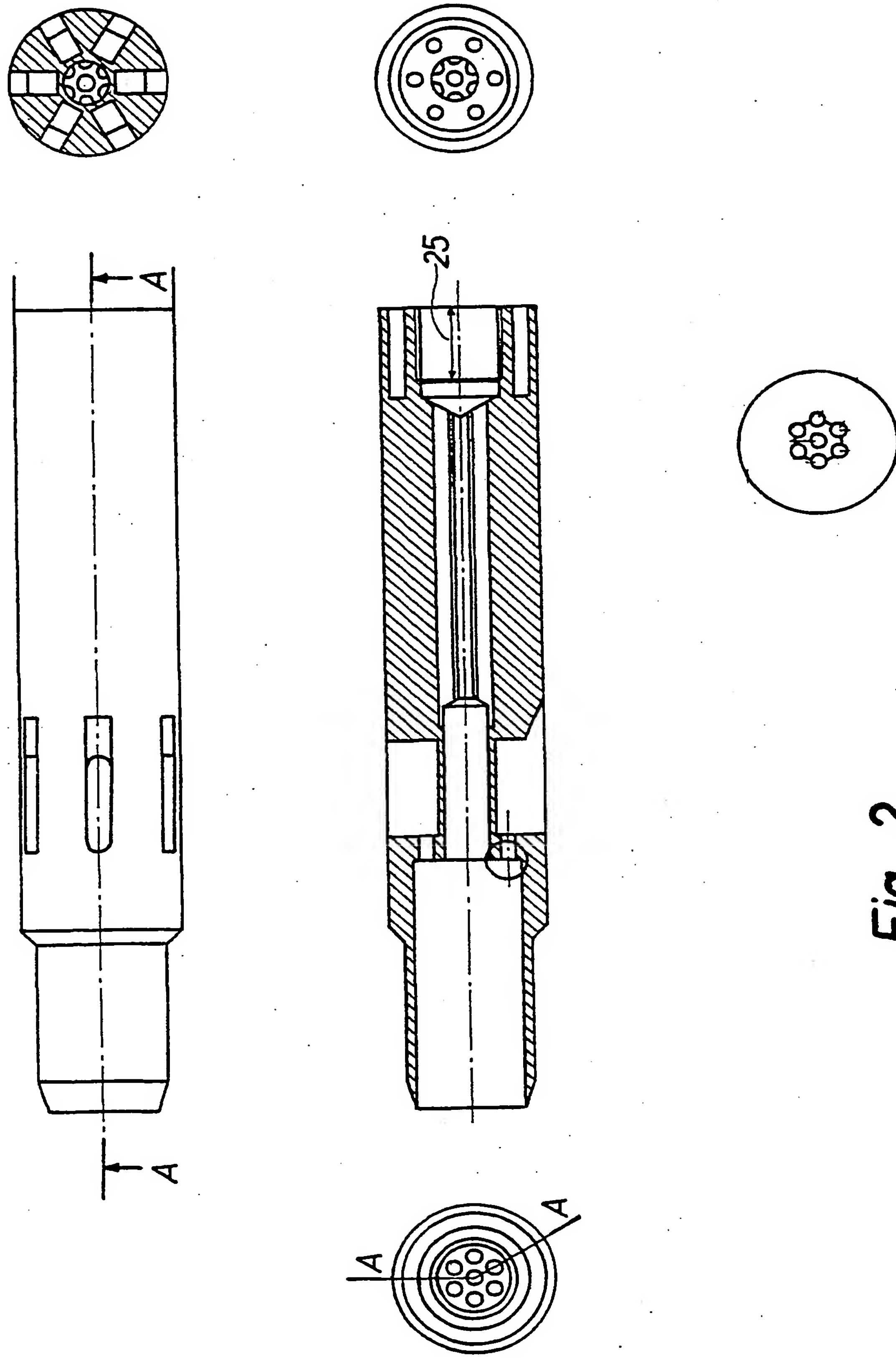

Fig. 2

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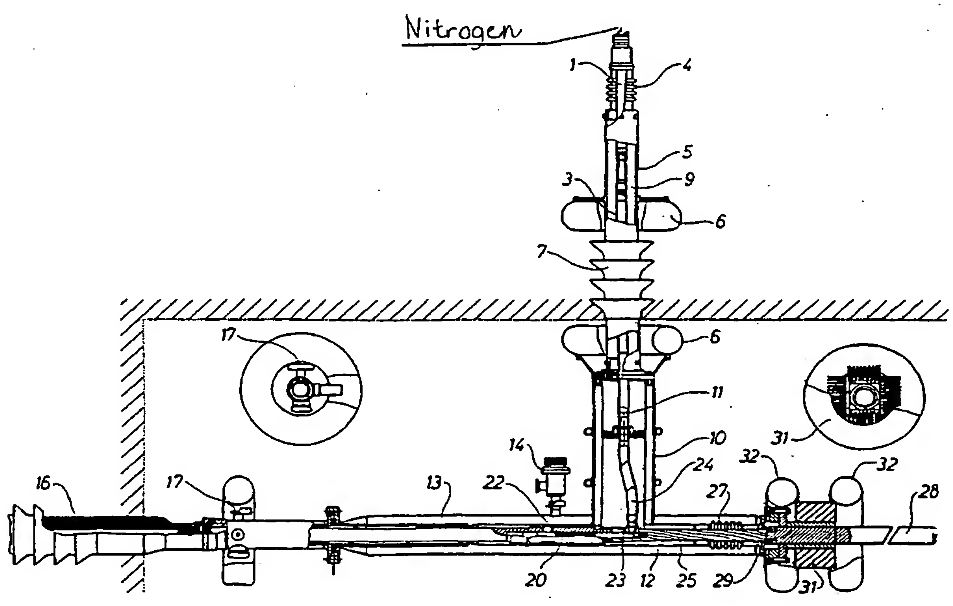
(54) Title: A TERMINAL CONNECTION FOR A SUPERCONDUCTIVE CABLE



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A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01R, H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 6049036 A (PIERO METRA), 11 April 2000 (11.04.00), see whole document --	1-13
A	US 5319154 A (JEAN-CLAUDE KERMARREC), 7 June 1994 (07.06.94), see whole document --	1-13
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A	US 3902000 A (ERIC B. FORSYTH ET AL), 26 August 1975 (26.08.75), see whole document --	1-13

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/ Name and mailing address of the International Searching Authority European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel(+31-70)340-2040, Tx 31 651 epo nl, Fax(+31-70)340-3016	Authorized officer Stig Edhborg/MN Telephone No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, Vol 2000,No 2, 29 February 2000 (29.02.00), abstract of JP 11-329526 A (SUMITOMO HEAVY IND LTD), 30 November 1999 (30.11.99), see abstract --	1-13
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SA 72303

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Information on patent family members

28/01/02

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